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ABSTRACT

Hydrographic observations from ten surveys spanning the Northeast U.S. Continental Shelf are combined into a descriptive overview of the broad-scale oceanographic conditions that were observed during 2010. Temperature and salinity observations are combined into six 2-month time periods in order to maximize both the spatial coverage of the data and its temporal resolution during the year. Maps of near-surface and near-bottom property distributions are presented for each bi-monthly period and time series of regional average properties are discussed for five geographic regions spanning the shelf: western Gulf of Maine (GOMW), eastern Gulf of Maine (GOME), Georges Bank (GBNK), and northern and southern Middle-Atlantic Bight (MABN and MABS, respectively). Surface conditions along the entire Northeast U.S. Continental Shelf were generally warm and fresh in 2010 relative to the reference period (1977-1987). Warming was largest in the spring and early summer, penetrating to the bottom throughout the region. The annual average air temperature over the Northeastern U.S. was warmer in 2010 than historical averages, with the greatest warming occurring during spring and summer. This may be responsible for the anomalously warm surface ocean temperatures at this time of year and for the enhanced warming that followed at depth in the near shore regions of the Middle Atlantic Bight. Freshening was greatest in the surface waters near the coast in the western Gulf of Maine and southern MAB during periods of maximum spring discharge, suggesting some influence from local fresh water sources in these regions. The surface freshening observed over Georges Bank and throughout the MAB penetrates to the bottom, while bottom waters in the Northeast Channel and deep basins of the GoM were saltier than normal reflective of the slope water influence in these regions.

INTRODUCTION

The Northeast Fisheries Science Center (NEFSC) conducts multiple surveys on the Northeast U.S. continental shelf each year in support of its ongoing mission to monitor the shelf ecosystem and assess how its components influence the distribution, abundance, and productivity of living marine resources. In support of this mission, the Oceanography Branch provides conductivity, temperature and depth (CTD) instruments to all NEFSC cruises for the measurement of water column profiles of temperature and salinity. In addition to providing oceanographic context to specific field programs, these data contribute to a growing database of historical measurements that are used to monitor seasonal and interannual variability in the water properties on the northeast continental shelf.

Broad-scale surveys, sampling the shelf from Cape Hatteras, North Carolina, into the Gulf of Maine, are conducted up to six times per year during shelf-wide spring and fall bottom trawl surveys and typically on four dedicated seasonal Ecosystem Monitoring (EcoMon) surveys. Profiles of conductivity, temperature and depth are collected at each station on these shelf-wide surveys. Observations are also collected on other more regionally focused NEFSC surveys, where station coverage varies depending on the objectives of the particular field program. During 2010, hydrographic data were collected on 10 individual NEFSC cruises, amounting to 1,807 profiles of temperature and salinity (Table 1). Here we present an annual summary of these observations, including surface and bottom distributions of temperature and salinity, as well as their anomalies relative to a consistent reference period. In addition, regional average values of temperature and salinity and their anomalies are computed for five different regions of the shelf during six bi-monthly periods. Finally, the volume and properties of the shelf water are examined for the Middle-Atlantic Bight region.

DATA AND METHODS

The Oceanography Branch provides CTD instrumentation and support to all NEFSC programs requesting this service. Training in instrument maintenance and operation, including deployment, data acquisition, recovery and preliminary processing, is provided as needed prior to sailing. On NEFSC surveys, CTD instruments are typically deployed in one of two modes: (1) during a bongo net tow, the CTD instrument is mounted on the conducting wire above the bongo frame and data are collected as a double oblique profile with the ship steaming at approximately 2 knots, (2) during a non-net tow, the CTD is mounted vertically on the wire and the sensors are soaked for one minute at the surface prior to descent. The sensors are not soaked at the surface prior to descent during bongo tows, rendering the upper 30 meters or more of the downcast unreliable. For this reason, the up-cast profile data are routinely processed as the primary data for each station.

In 2010, hydrographic data were collected aboard the NOAA ships *Delaware II* and *HB Bigelow*, and the R/V *HR Sharp* using a combination of Seabird Electronics SBE-19 and SBE-19+ SEACAT profilers and SBE 9/11 CTD units (Table 1). All raw CTD profile data were processed ashore, using standard Seabird Electronics software to produce 1-decibar averaged profiles in ascii-formatted files. Water samples were collected twice daily at sea during vertical casts. Following each cruise, these samples were analyzed using a Guildline AutoSal laboratory salinometer to provide quality control for the CTD salinity data. A salinity offset was applied to instrument data if the mean difference between the reference Autosal readings and the CTD values exceeded +/- 0.01 (a threshold chosen based on the expected instrument accuracy.) Vertical density profiles were examined for inversions due to bad conductivity or temperature readings and/or sensor misalignment. Egregious cases were replaced with a flag value. The processed hydrographic data were loaded into ORACLE database tables and made publically available via anonymous ftp (ftp://ftp.nefsc.noaa.gov/pub/hydro). Cruise reports have been prepared for each survey listed in Table 1 and are available online (http://www.nefsc.noaa.gov/epd/ocean/MainPage). Readers are referred to the individual cruise reports for notes, property maps and aggregate data specific to a particular survey.

Here, we aim to provide a descriptive overview of the hydrographic sampling that was conducted in 2010 and to characterize the broad-scale oceanographic conditions that were observed. In order to maximize both the spatial coverage of the data and its temporal resolution, the processed 2010 CTD data have been sorted into six 2-month time bins. Maps of near-surface and near-bottom temperature and salinity have been produced from profile data falling within each 2-month period. Surface fields include the shallowest observed temperature/salinity at each station that is also in the upper 5 meters of the water column, while bottom maps include the deepest observation at each station that also falls within 10 meters of the reported water depth. In order to examine the spatial and temporal variability over broader areas of the shelf, average values have been computed from the data within five sub-regions spanning the Northeast U.S. Continental Shelf (Figure 1). Regional averages have been computed for the bi-monthly binned fields (Tables 1 and 2) and for individual cruises (Appendix Tables 1-5).

In order to characterize variability that is not related to seasonal forcing, anomalies have been calculated at each station relative to a standard reference period (1977-1987). During this period the NMFS Marine Resources Monitoring and Prediction (MARMAP) program repeatedly occupied stations spanning the entire Northeast U.S. Shelf so that an annual cycle could be constructed for water properties across all regions of the northeast shelf (Mountain et al., 2004; Mountain and Holzwarth, 1989). The anomalies presented here are defined as the difference between the observed 2010 value at individual stations and the expected value for each location and time of year based on this reference period. Similarly, regional anomalies are the area-weighted average of these anomalies within a given domain. The methods used and an explanation of uncertainties is presented in Holzwarth and Mountain (1990).

Finally, we calculate the temperature, salinity and volume of the shelf water in the Middle-Atlantic Bight during 2010 and relate this to the conditions observed during the MARMAP reference period. Following Mountain (2003), the shelf water mass is defined as water within the upper 100 meters having salinity less than 34. For each survey in 2010, the area of a sub-region was apportioned among its stations by an inverse distance squared weighting. The shelf water volume at a given station is the thickness of the shelf water at the station multiplied by its apportioned area, and the total shelf water volume within the sub region is the sum of these products for all stations within the region. Similarly, the average temperature and salinity was calculated in the shelf water layer at each station and multiplied by the total shelf water volume for that station. The sum of these products over all stations within a given sub-region, divided by the total shelf water volume for the region, determines the volume-weighted average temperature and salinity. Anomalies in the property and volume of the shelf water mass are calculated relative to like variables derived from MARMAP hydrographic data, as described above. Hence, here regional anomalies are computed as the mathematical difference between regional averages, *not* an average of the anomalies computed for a given sub-region.

RESULTS

Table 1 provides a listing of the NEFSC cruises that collected hydrographic data in 2010. In total, 1807 profiles of temperature and salinity were collected, processed and archived during the year. Combining the hydrographic data from multiple cruises into bi-monthly bins improves the spatial coverage compared with that of individual surveys, enabling us to examine the spatial and temporal patterns in hydrography over the region. Nonetheless, there are still significant gaps in several of the bi-monthly distribution maps shown in Figure 2, particularly in the Middle Atlantic Bight during July/August and in the Gulf of Maine during January/February and September/October. These gaps result in part from a misalignment between the bi-monthly periods and the longer bottom trawl surveys that work from south to north along the shelf. For instance, the September/October period encompass all but the final third of the fall ground fish survey, when sampling was focused in the Gulf of Maine. In some cases poor weather slowed sampling operations and shortened surveys. The August EcoMon survey worked from north to south, opposite normal operations, to improve temporal coverage in the Gulf of Maine. However, several days were lost to poor weather and an emergency evacuation, leaving large areas of the Middle Atlantic Bight unsampled. Heavy weather during the February EcoMon survey prevented sampling in the eastern Gulf of Maine. These large gaps in station coverage preclude the calculation of a representative regional average surface/bottom temperature and salinity value during July/August in the southern MAB and during January/February in the eastern Gulf of Maine (Tables 2 and 3, Figures 3 and 4). While station coverage is better during all other periods, not all of the average properties reported are true area-weighted averages representative of the entire region. Those cases are flagged in Tables 2 and 3 and the reader should keep this in mind when interpreting results.

Overall, surface conditions along the entire Northeast U.S. Continental Shelf were warm and fresh in 2010 relative to the reference period, except in the southern MAB where temperatures were near reference values (Figures 3 and 4). Freshening was greatest in the surface waters of the western Gulf of Maine and southern MAB, suggesting some influence from local fresh water sources in these regions (Figure 4). Bottom waters were uniformly warm throughout the year in the Gulf of Maine and on Georges Bank (Figure 3). Weaker warming was observed in the northern MAB and bottom temperatures were near reference values in the southern MAB. Freshening was observed near the bottom on Georges Bank and in the Middle Atlantic Bight. Bottom waters in the western Gulf of Maine were fresher than normal early in the year, becoming saltier than normal later in the year. Surprisingly, bottom waters in the eastern Gulf of Maine were not significantly different than the reference salinity at any point in the year despite the fact that deep inflow to the Gulf of Maine was warmer and saltier in 2010, close to the upper limit of the historical range. Compared with the reference period, the shelf water in the MAB was up to 0.5 units fresher than was observed during the MARMAP period (shelf water is defined by salinities less than 34; Figure 5). The shelf water temperature fluctuated between warm and cold anomalies during 2010 but the volume was high relative to the reference period throughout the year. This suggests that the shelf/slope front was consistently located offshore of its position during the MARMAP period (Figure 5).

Details related to the temporal trends in Figures 3 and 4 are explored in surface and bottom property distribution maps (Figures 6-11). Maps of surface temperature reveal the seasonal cycle of warming and cooling over the region, with warmest temperatures observed at the surface during late summer (Figure 6-11a). Even though regional averages indicate warming over most of the region relative to the MARMAP reference period, the details of this warming varies from region to region. Surface temperature anomaly maps in the Gulf of Maine tend to be uniformly warm, with the exception of January/February. By contrast, maps in the MAB are less uniform, characterized by a mixture of warmer and colder anomalies (Figures 6-11b). Maps of surface salinity show the seasonal influence of freshwater discharge in the nearshore regions, with the freshest waters appearing very near the coast in the eastern Gulf of Maine and MAB in March/April followed by more wide-spread freshening over these regions in May/June (Figures 7a and 8a). While overall surface waters were fresher than normal in 2010, the largest anomalies were observed near the coast in the vicinity of major freshwater sources (e.g. western Gulf of Maine, Hudson River, Delaware and Chesapeake Bays) during periods of maximum spring discharge (March/April and May/June; Figures 7b and 8b).

Maps of near bottom salinity and salinity anomaly suggest that the freshening that is observed at the surface penetrates to the bottom on Georges Bank and throughout the MAB (Figures 4 and 6-11). However, the same is not true in the Gulf of Maine where slope water dominates the lower layer properties. Near-bottom temperature and salinity anomalies in Northeast Channel and in the deep basins of the GoM suggest that the slope water was warmer and saltier from March through June during 2010 (Figures 7b and 8b).

Maps of near-bottom temperature show the seasonal formation of the cold pool in the Middle Atlantic Bight, with coldest temperatures observed during the May/June period (Figure 8a). The accompanying maps of near-bottom temperature anomaly suggest that temperatures in the cold pool were colder than normal, particularly in the vicinity of the temperature minimum and along the shelf to the south (Figure 8b). By September/October the cold pool has begun to weaken and warm, becoming less coherent in the central MAB (Figure 10a). Localized cold anomalies scattered along the axis of the temperature minimum (Figure 10b) are indicative of interannual variations in the erosion of this feature. By November/December, the cold pool is completely eroded and near-bottom shelf temperatures in the southern MAB are warmer than normal (Figure 11a and 11b).

The erosion of the cold pool in late summer is preceded by warming of bottom waters near the coast in September/October (Figure 10a). This is consistent with historical observations in this region, which indicate that by late summer the effects of seasonal heating extend all the way to the ocean bottom in the near-shore regions (Castelao et al., 2010). The anomaly fields shown in Figure 10b suggest that waters near the bottom were up to 2 degrees warmer in late-summer 2010 than during the reference period.

Based on the climate summaries compiled by the Northeast Regional Climate Center (http://www.nrcc.cornell.edu), the air temperature across the Northeastern U.S. was warmer than the long term mean throughout the year except December (Figure 12). The annual cycle of heating and cooling in 2010 was aligned with the long-term annual cycle but warming was enhanced during spring (up to 5°F warmer in March and April), remaining warm through late summer (September). This timing is coincident with the largest surface temperature anomalies on the Northeast U.S. Shelf (Figure 3). Overall, the annual mean air temperature across the Northeastern U.S. was almost 2°F warmer than long-term annual mean values.

According to the Northeast Regional Climate Center records, the annual mean precipitation over the Northeastern U.S. was near normal, although several months recorded significant departures from the long-term average (referenced to 1971-2000). Precipitation was almost 1.5” above normal in March and nearly 2.5” above normal in October 2010. The increase in March may account in part for the fresh surface conditions observed in the March/April time period, particularly in regions where freshwater discharge has a significant influence (e.g.

western Gulf of Maine and southern MAB; Figure 4). However, a more thorough analysis would be needed to discriminate between local freshening due to precipitation and river run-off and freshening due to advection from remote sources. Anomaly maps suggest that a saltier variety of near-bottom waters may have been entering the eastern Gulf of Maine through Northeast Channel and along the southwestern Scotian Shelf during May/June (Figure 8b). These saltier source waters mix vertically with surface waters within the Gulf of Maine, including the near surface and inshore waters where freshening due to increased precipitation will be greatest.

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Table 1. Listing of 2010 NOAA Northeast Fisheries Science Center cruises supported by the Oceanography Branch.

Cruise	Program	Dates	Region(s)[1]	Gear	Casts
DEL1001	EcoMon/NASA	2 - 18 Feb	MAB, GB, West GOM	SBE[2]-19+ , 9/11+	131
DEL1002	NOAA/LMRCSC	28 Feb - 5 Mar	MAB	SBE-19	12
HB1002	Spring Bottom Trawl	28 Feb - 2 May	Full Shelf	SBE-19+	390
S1001	Scallop Survey	12 May - 30 Jun	MAB, GB	SBE-9/11+	141
DEL1004	EcoMon/NASA	26 May - 9 Jun	Full Shelf	SBE-19, 9/11+	196
DEL1009	EcoMon	19 Aug - 1 Sep	North MAB, GB, GOM	SBE-19+	109
HB1005	Fall Bottom Trawl	9 Sep - 3 Dec	Full Shelf	SBE-19+	356
DEL1010	Hydro Acoustic Survey	11 Sep - 21 Oct	GB, GOM	SBE-19+	146
DEL1011	Benthic Habitat	27 - 30 Oct	GB	SBE-19+	73
DEL1012	EcoMon/NASA	5 Nov - 5 Dec	Full Shelf	SBE-19+, 9/11+	253

[1] Regional Abbreviations: Gulf of Maine (GOM), Georges Bank (GB), Mid Atlantic Bight (MAB)
[2] Seabird Electronics (SBE)

Table 2. 2010 regional average surface and bottom temperature values computed from CTD data that were sorted into six 2-month time periods for the five regions of the Northeast U.S. continental shelf. Boundaries of Gulf of Maine East (GOME), Gulf of Maine West (GOMW), Georges Bank (GB), Mid Atlantic Bight North (MABN), and Mid Atlantic Bight South (MABS) are shown in Figure 1.

		SURFACE						BOTTOM					
Region	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
						January-February							
GOME	46	2	4.59	-0.45	0.69	5.75	1	2	6.48	0.10	0.64	7.05	1
GOMW	47	37	4.74	0.07	0.19	0.99	1	31	5.49	0.83	0.18	1.33	1
GB	45	30	5.40	-0.16	0.21	0.60	0	27	5.82	-0.07	0.25	1.11	0
MABN	38	15	5.70	-0.39	0.32	1.54	1	13	6.52	0.19	0.34	2.06	1
MABS	42	44	6.05	0.34	0.20	0.77	1	37	5.77	0.82	0.22	0.88	1
						March-April							
GOME	105	31	5.25	0.44	0.17	0.92	0	28	7.77	1.14	0.19	0.79	0
GOMW	112	51	7.05	1.60	0.15	0.92	0	51	6.10	1.00	0.13	0.70	0
GB	98	57	6.80	1.67	0.14	1.44	0	45	6.58	1.43	0.17	0.95	0
MABN	82	55	6.08	1.61	0.18	1.48	0	47	5.93	0.86	0.22	1.46	0
MABS	68	93	5.71	-0.04	0.14	1.47	0	77	5.38	-0.36	0.17	1.32	0
						May-June							
GOME	162	31	11.64	1.84	0.17	3.17	1	25	8.55	0.42	0.19	4.27	1
GOMW	158	44	13.25	2.37	0.18	1.65	0	93	6.90	0.98	0.18	2.93	1
GB	160	92	11.51	1.37	0.12	1.39	0	75	9.04	0.81	0.14	1.66	0
MABN	151	49	13.87	1.78	0.20	1.70	0	43	7.75	0.62	0.22	1.37	0
MABS	144	90	14.88	0.33	0.14	1.09	0	84	8.68	-0.53	0.16	1.68	0
						July-August							
GOME	234	19	16.74	1.74	0.25	1.40	0	14	9.05	0.71	0.27	1.86	0
GOMW	234	23	18.40	1.60	0.22	1.53	0	21	7.59	1.22	0.19	1.20	0
GB	241	41	18.73	2.54	0.18	1.48	0	36	12.53	0.24	0.17	1.89	1
MABN	243	3	23.42	4.23	0.74	0.36	1	2	9.76	-1.29	0.97	2.52	1
MABS													
						September-October							
GOME	282	68	14.51	0.10	0.12	1.98	1	67	9.91	-0.09	0.12	3.05	1
GOMW	280	85	14.28	0.51	0.12	1.71	1	82	8.16	1.79	0.10	2.48	1
GB	294	144	14.30	0.01	0.14	0.99	0	125	12.78	0.39	0.18	1.53	0
MABN	280	65	17.90	0.78	0.17	1.43	0	50	13.70	1.26	0.22	1.82	0
MABS	260	94	21.84	-0.04	0.13	1.11	0	80	14.78	0.62	0.16	1.95	0
						November-December							
GOME	318	36	10.82	0.40	0.16	0.60	0	31	9.61	1.16	0.18	1.14	0
GOMW	322	94	10.30	0.57	0.13	0.60	0	86	8.83	1.48	0.11	0.82	0
GB	325	57	12.38	0.78	0.14	1.72	0	50	11.98	0.98	0.16	1.56	0
MABN	320	41	12.87	-0.20	0.23	0.87	0	36	12.64	-0.02	0.25	0.99	0
MABS	312	43	14.89	-0.34	0.21	0.65	0	38	14.45	-0.03	0.22	0.93	1

"Region", the geographic region of the northeast continental shelf: "CD", the calendar mid-date of all the stations within a region for a time period: "#obs", the number of observations included in each average: "Temp", the areal average temperature: "Anomaly", the areal average temperature anomalies: "SDV1",the standard deviation associated with the average temperature anomaly: "SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived: "Flag", a value of "1" indicates that a true areal average could not be calculated due to poor station coverage. The areal averages listed were derived from a simple average of the observations within the region.

Table 3. 2010 regional average surface and bottom salinity values computed from CTD data that were sorted into six 2-month time periods for the five regions of the Northeast U.S. continental shelf. Boundaries of Gulf of Maine East (GOME), Gulf of Maine West (GOMW), Georges Bank (GB), Mid Atlantic Bight North (MABN), and Mid Atlantic Bight South (MABS) are shown in Figure 1.

		SURFACE						BOTTOM					
Region	CD	#obs	Salt	Anomaly	SDV1	SDV2	Flag	#obs	Salt	Anomaly	SDV1	SDV2	Flag
						January-February							
GOME	46	2	32.55	-0.57	0.43	2.63	1	2	33.48	-0.20	0.41	3.01	1
GOMW	47	37	32.57	-0.28	0.13	0.45	1	31	32.89	-0.30	0.11	0.56	1
GB	45	30	32.94	-0.13	0.12	0.29	0	27	33.09	-0.13	0.15	0.43	0
MABN	38	15	33.02	-0.14	0.23	0.88	1	13	33.37	-0.11	0.20	0.86	1
MABS	42	43	33.24	0.11	0.15	0.50	1	36	33.31	0.25	0.14	0.45	1
						March-April							
GOME	105	31	31.83	-0.69	0.12	0.42	0	28	33.99	0.00	0.10	0.45	0
GOMW	112	51	31.60	-0.88	0.10	0.43	0	51	33.05	-0.31	0.08	0.39	0
GB	98	57	32.84	-0.16	0.09	0.75	0	45	32.92	-0.24	0.10	0.46	0
MABN	82	55	32.39	-0.50	0.12	2.49	0	47	32.89	-0.47	0.13	0.47	0
MABS	68	93	32.81	-0.36	0.11	2.22	0	77	33.18	-0.31	0.10	0.54	0
						May-June							
GOME	162	31	32.00	-0.51	0.11	0.82	1	25	33.33	-0.04	0.11	1.13	1
GOMW	158	44	31.44	-0.61	0.12	0.43	0	93	33.20	-0.25	0.10	0.78	1
GB	160	92	32.26	-0.56	0.07	0.30	0	75	32.63	-0.45	0.09	0.40	0
MABN	151	49	31.91	-0.51	0.13	0.31	0	43	32.66	-0.47	0.13	0.43	0
MABS	144	89	31.39	-0.82	0.11	0.62	0	84	32.58	-0.72	0.10	0.47	0
						July-August							
GOME	234	19	32.22	-0.15	0.19	0.34	0	14	34.23	-0.02	0.15	0.37	0
GOMW	234	23	31.81	-0.17	0.14	0.34	0	21	33.42	0.09	0.12	0.37	0
GB	241	41	32.32	-0.32	0.11	0.43	0	36	32.51	-0.30	0.10	0.71	1
MABN	243	3	33.74	0.82	0.45	0.32	1	2	33.00	-0.37	0.55	0.90	1
MABS													
						September-October							
GOME	282	68	32.21	-0.26	0.08	0.85	1	67	33.71	0.01	0.07	0.82	1
GOMW	280	83	32.21	-0.13	0.08	0.77	1	82	33.85	0.25	0.06	0.71	1
GB	294	144	32.39	-0.38	0.08	0.35	0	125	32.84	-0.22	0.11	0.36	0
MABN	280	65	32.60	-0.15	0.11	0.66	0	50	32.98	-0.34	0.13	0.51	0
MABS	260	94	32.42	0.14	0.10	0.79	0	80	32.80	-0.46	0.10	0.71	0
						November-December							
GOME	318	36	32.71	-0.01	0.11	0.33	0	31	34.28	-0.02	0.10	0.35	0
GOMW	322	94	32.87	0.07	0.08	0.26	0	86	33.73	0.13	0.06	0.24	0
GB	325	57	33.04	0.20	0.09	0.66	0	50	33.22	0.23	0.09	0.57	0
MABN	320	41	32.57	-0.39	0.15	0.35	0	36	32.94	-0.46	0.15	0.47	0
MABS	312	43	32.51	-0.32	0.16	0.92	0	38	32.81	-0.25	0.14	0.57	1

"Region", the geographic region of the northeast continental shelf: "CD", the calendar mid-date of all the stations within a region for a time period: "#obs", the number of observations included in each average: "Salt", the areal average salinity: "Anomaly", the areal average salinity anomalies: "SDV1",the standard deviation associated with the average salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
"Flag", a value of "1" indicates that a true areal average could not be calculated due to poor station coverage. The areal averages listed were derived from a simple average of the observations within the region.

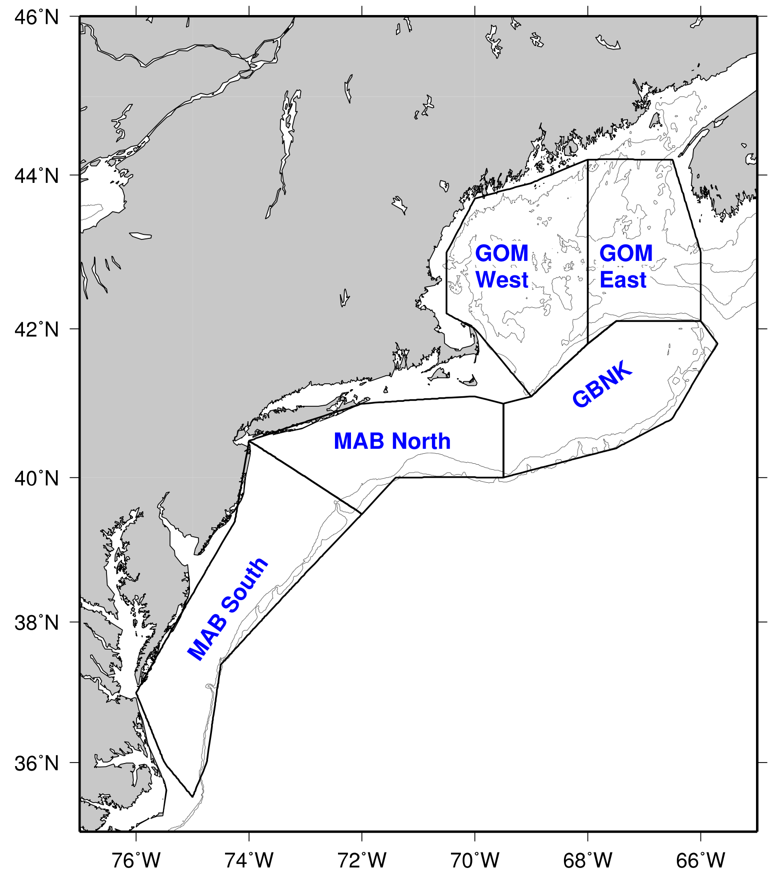

Figure 1. Region designations for the Northeast U.S. Continental Shelf: Gulf of Maine (GOM), Georges Bank (GB), Mid Atlantic Bight (MAB). The 100 m and 200 m isobaths are also shown.

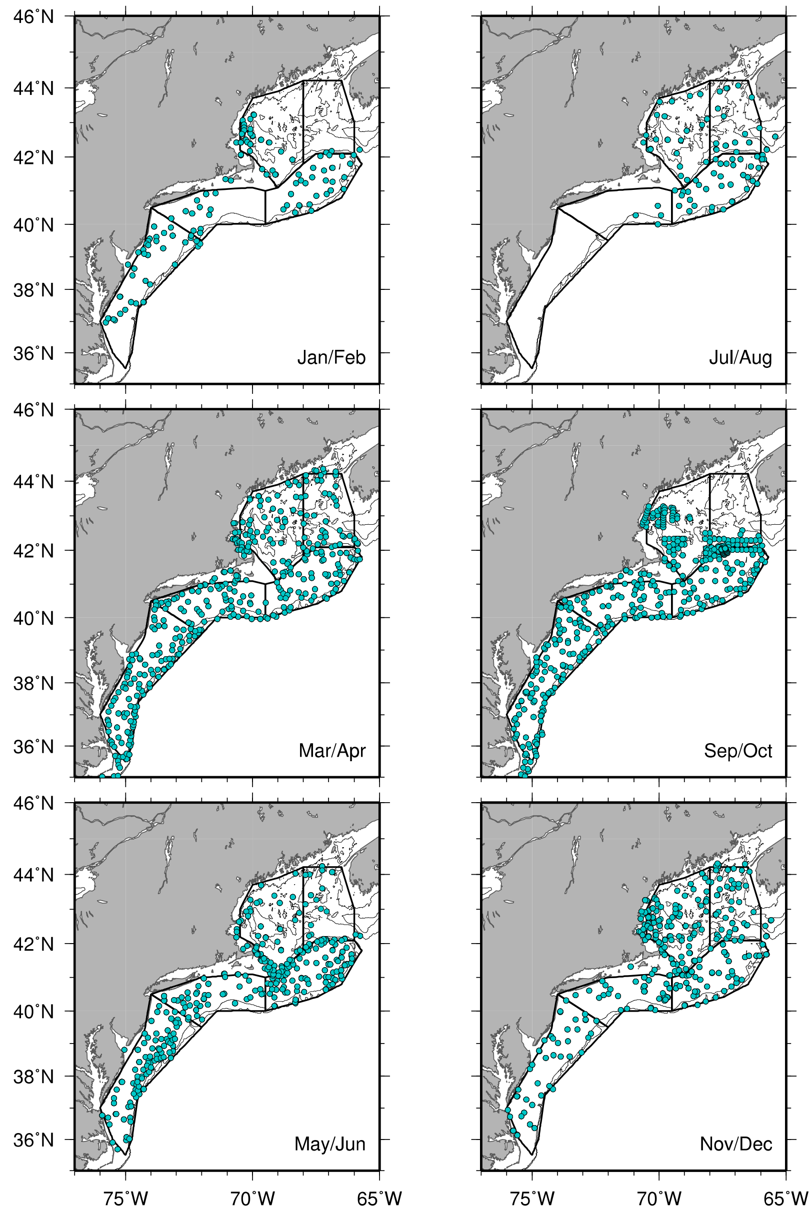

Figure 2. 2010 station distributions for each 2-month time period. The regional boundaries are also overlain. Contours indicate the 100 and 200-meter isobaths.

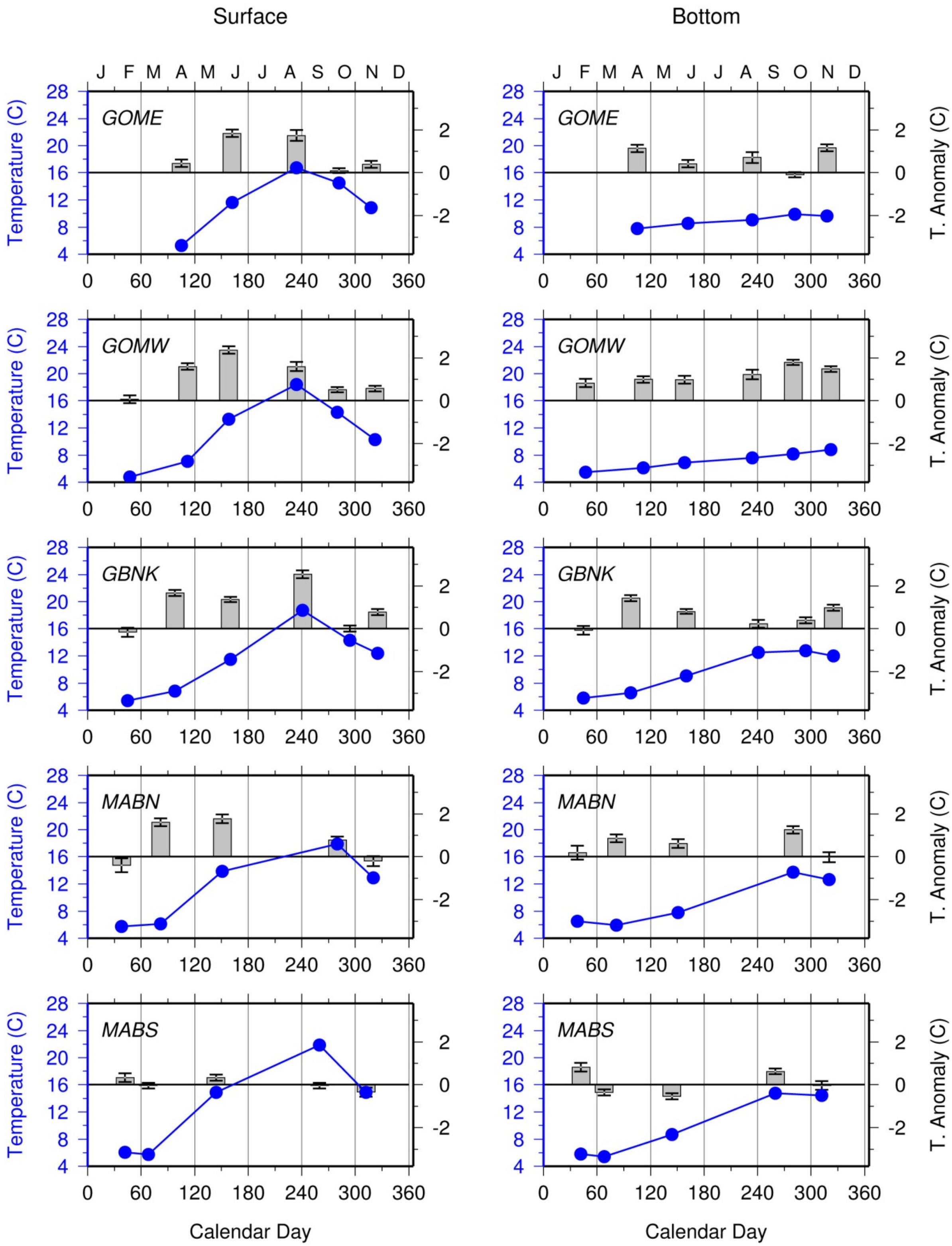

Figure 3. Time series of the 2010 regional surface (left) and bottom (right) temperatures (blue) and anomalies (bars) as a function of calendar day. Error bars are indicated for the anomaly estimates.

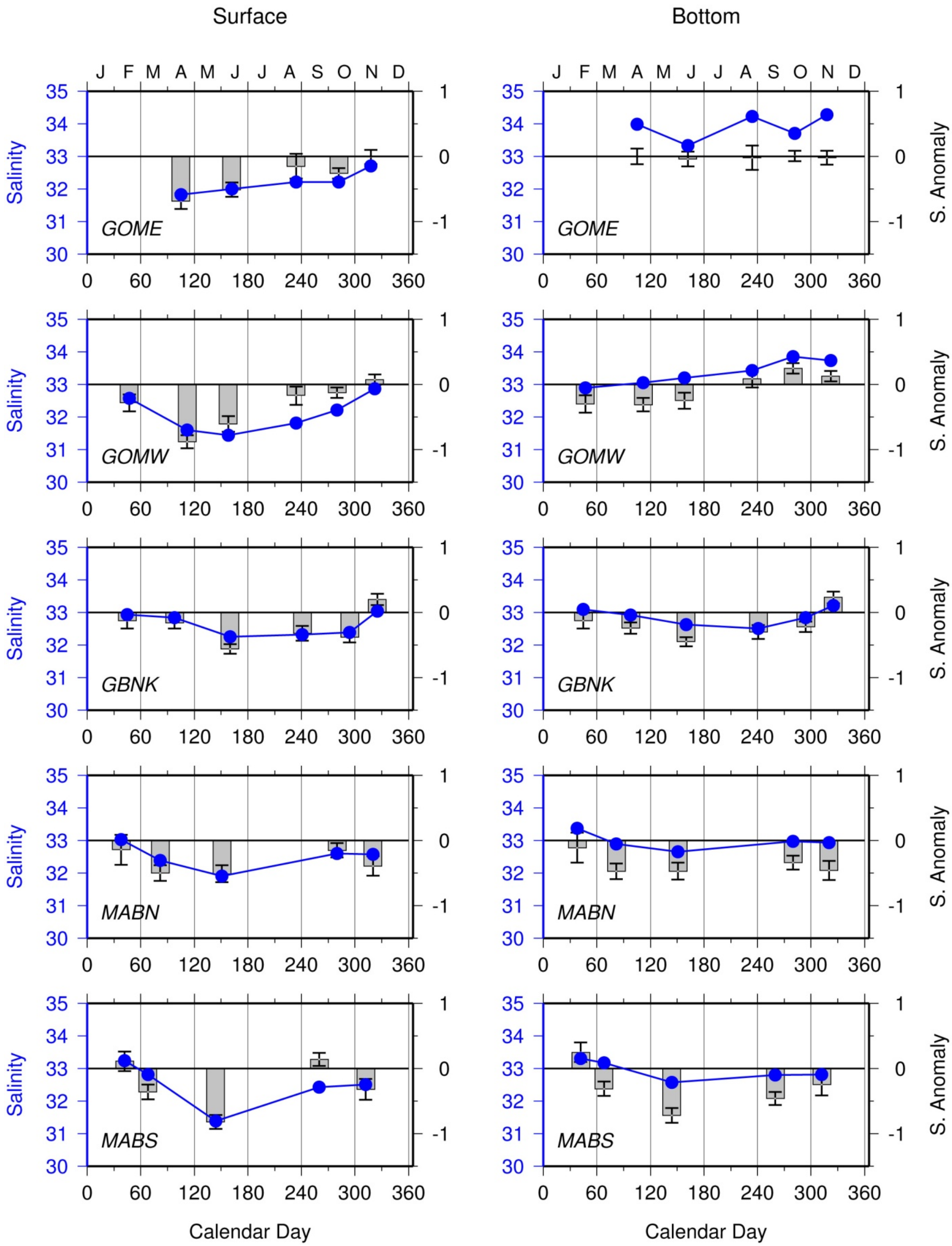

Figure 4. Time series of the 2010 regional surface (left) and bottom (right) salinities (blue) and anomalies (bars) as a function of calendar day. Error bars are indicated for the anomaly estimates.

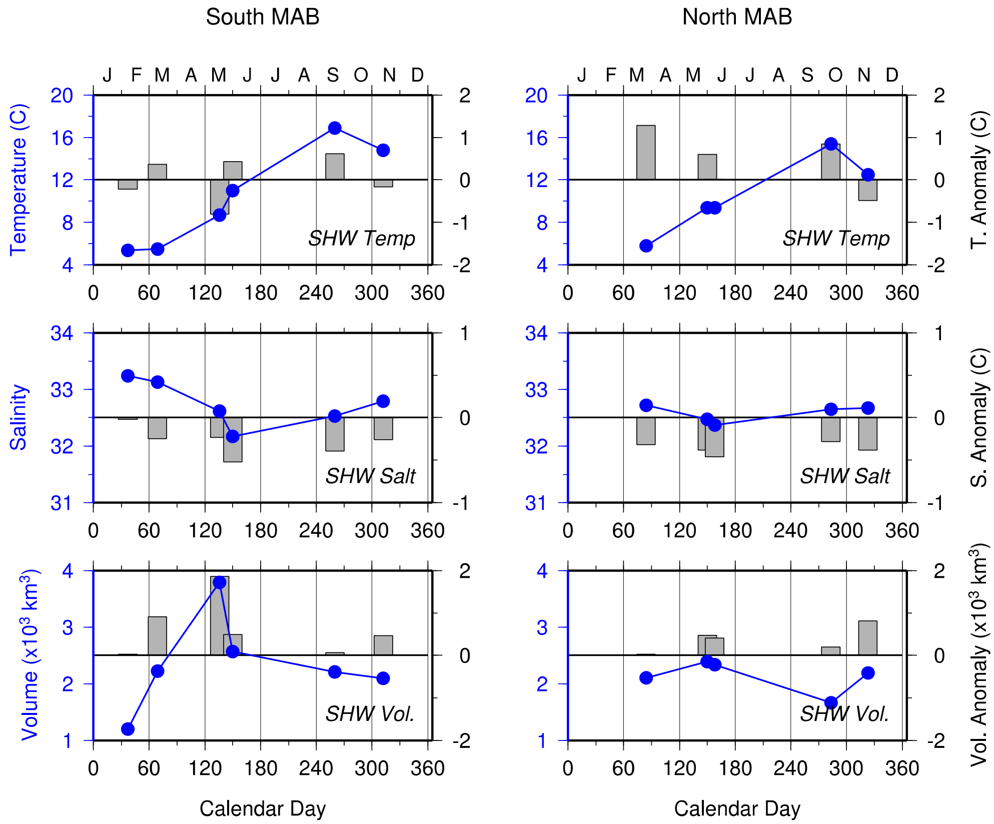

Figure 5. Time series of the 2010 regional shelf water temperature, salinity, and volume as a function of calendar day shown in blue for the southern (left) and northern (right) Middle Atlantic Bight. The vertical bars show the corresponding shelf water anomalies.

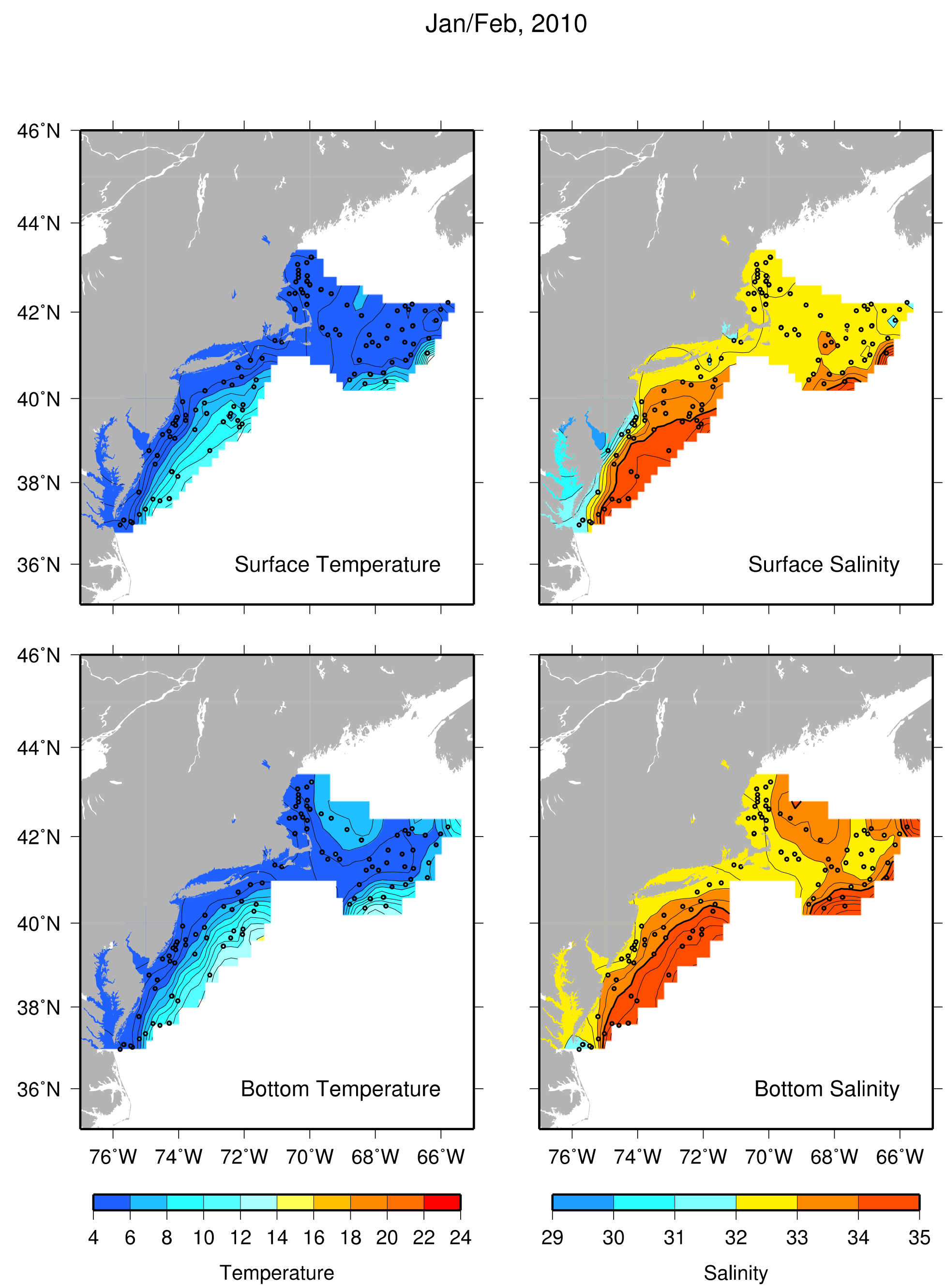

Figure 6a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during January-February 2010. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

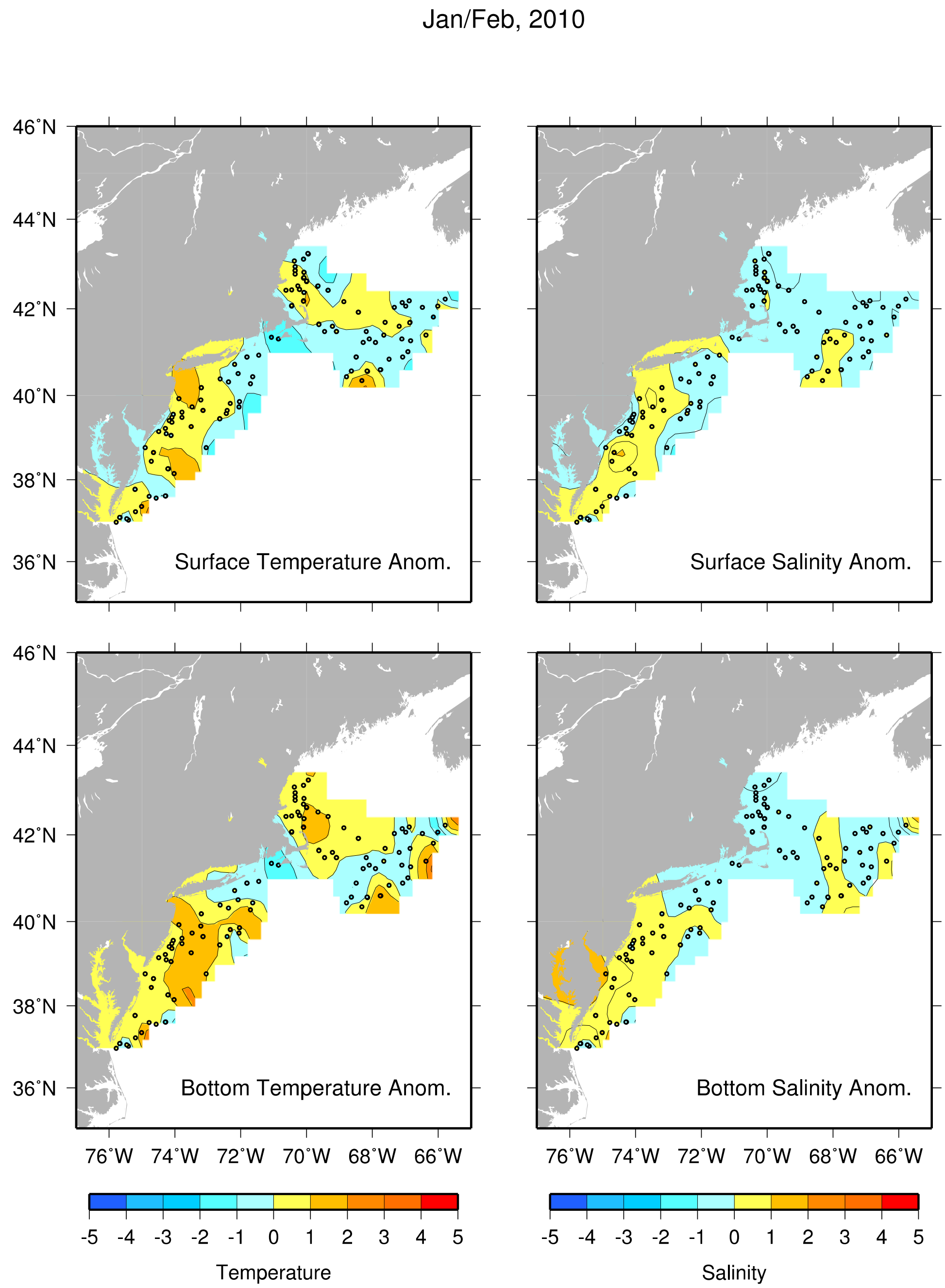

Figure 6b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during January-February 2010. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

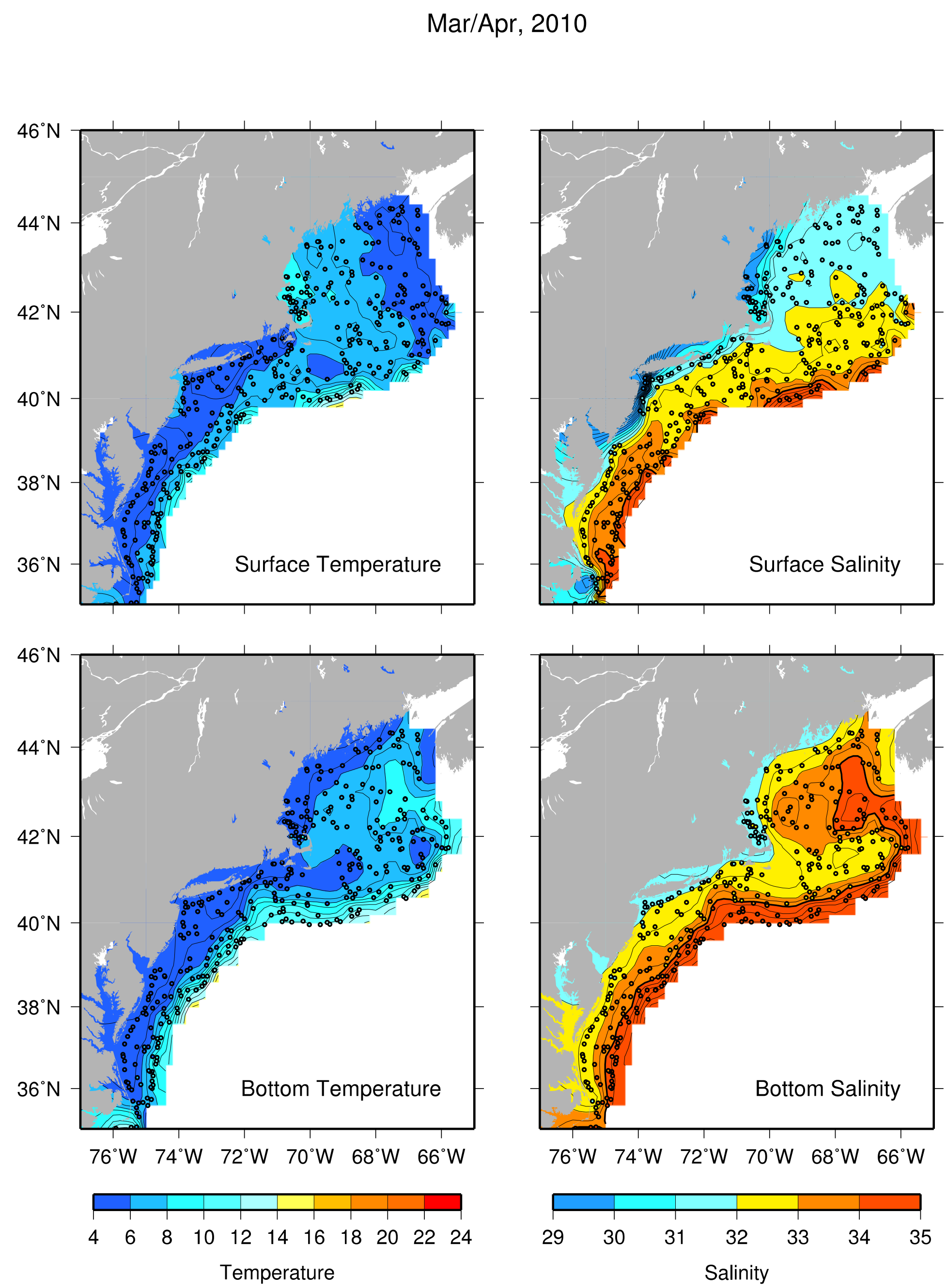

Figure 7a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during March-April 2010. Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

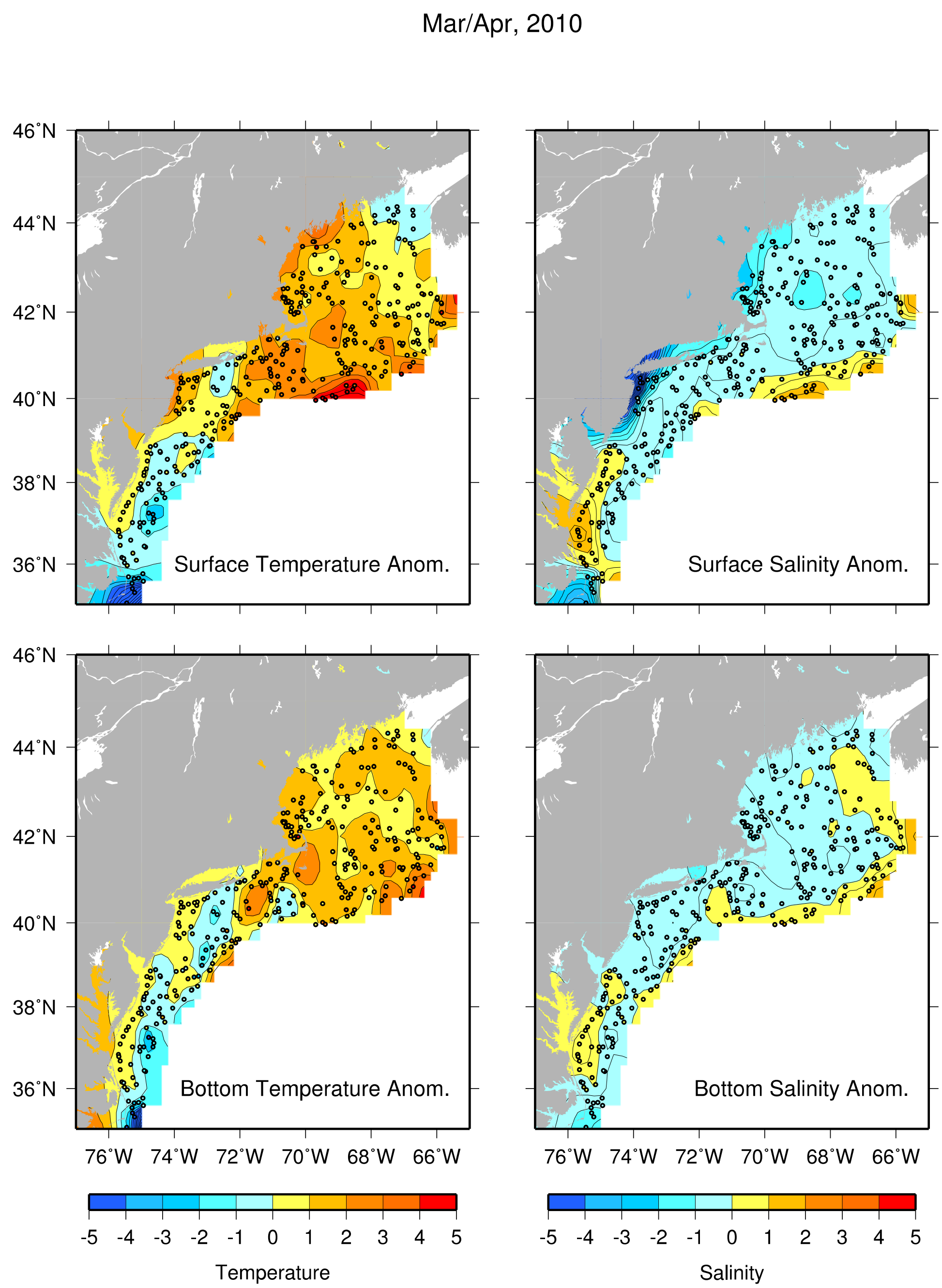

Figure 7b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during March-April 2010. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

May/Jun, 2010

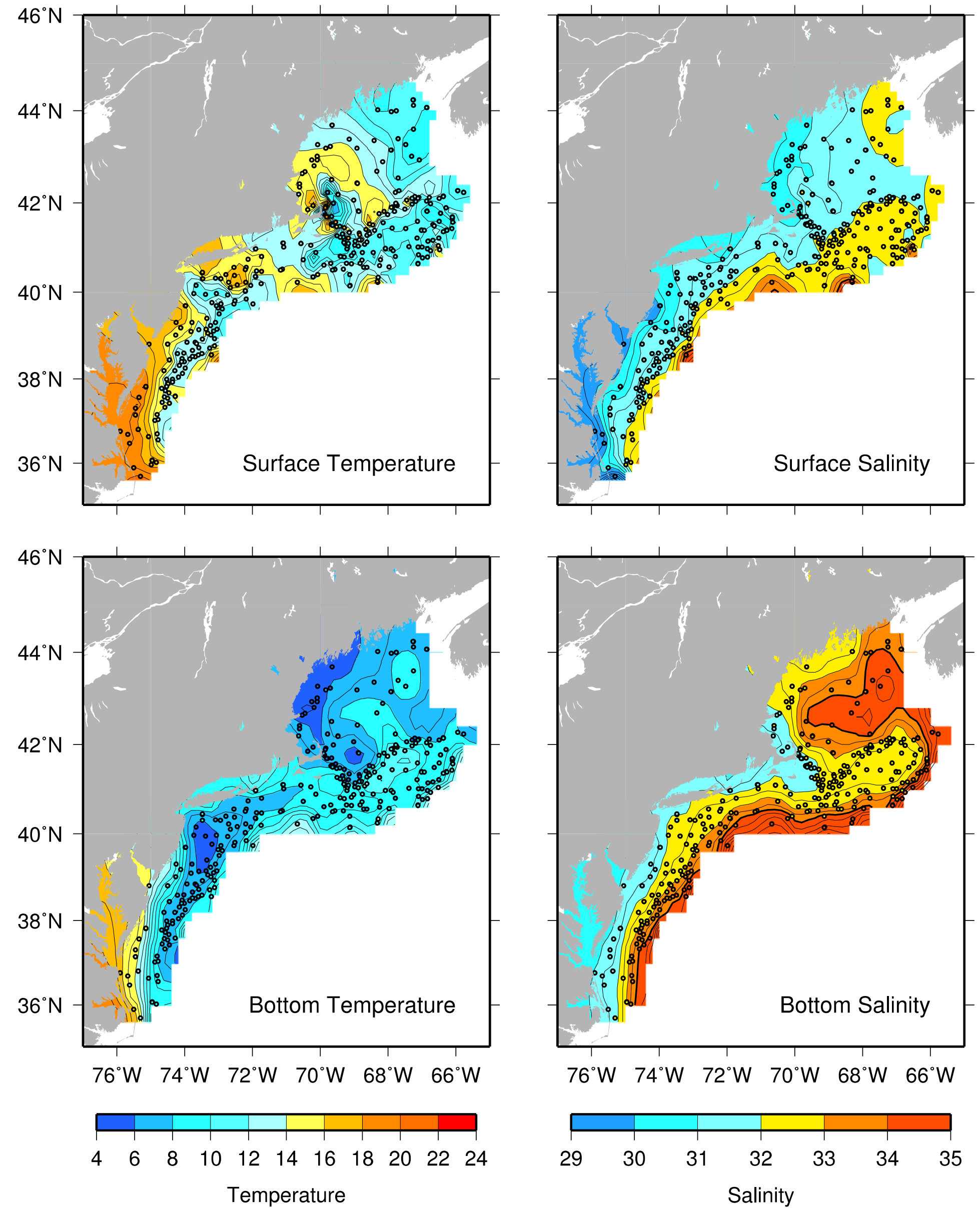

Figure 8a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during May-June 2010.Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

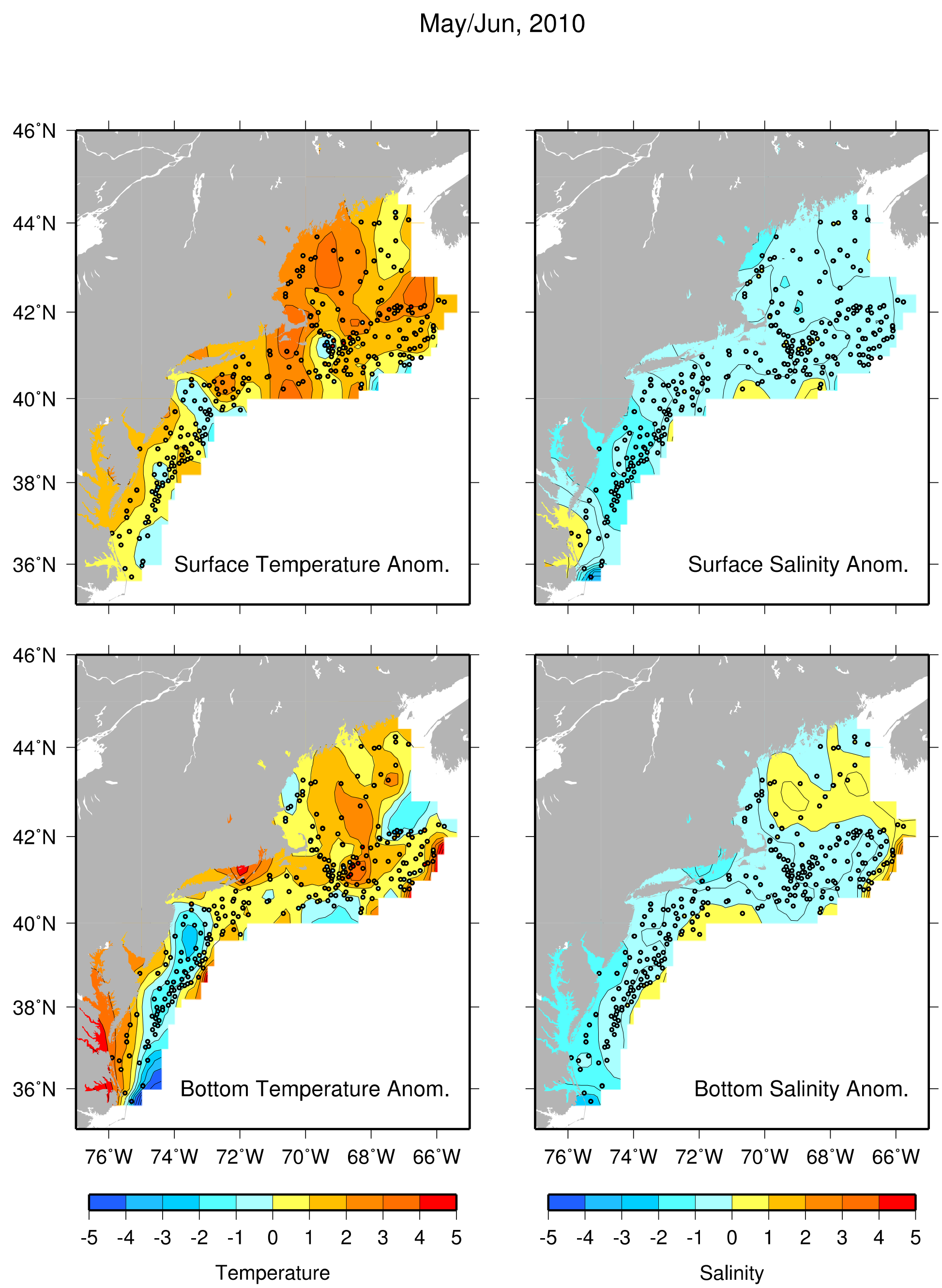

Figure 8b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during May-June 2010. Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

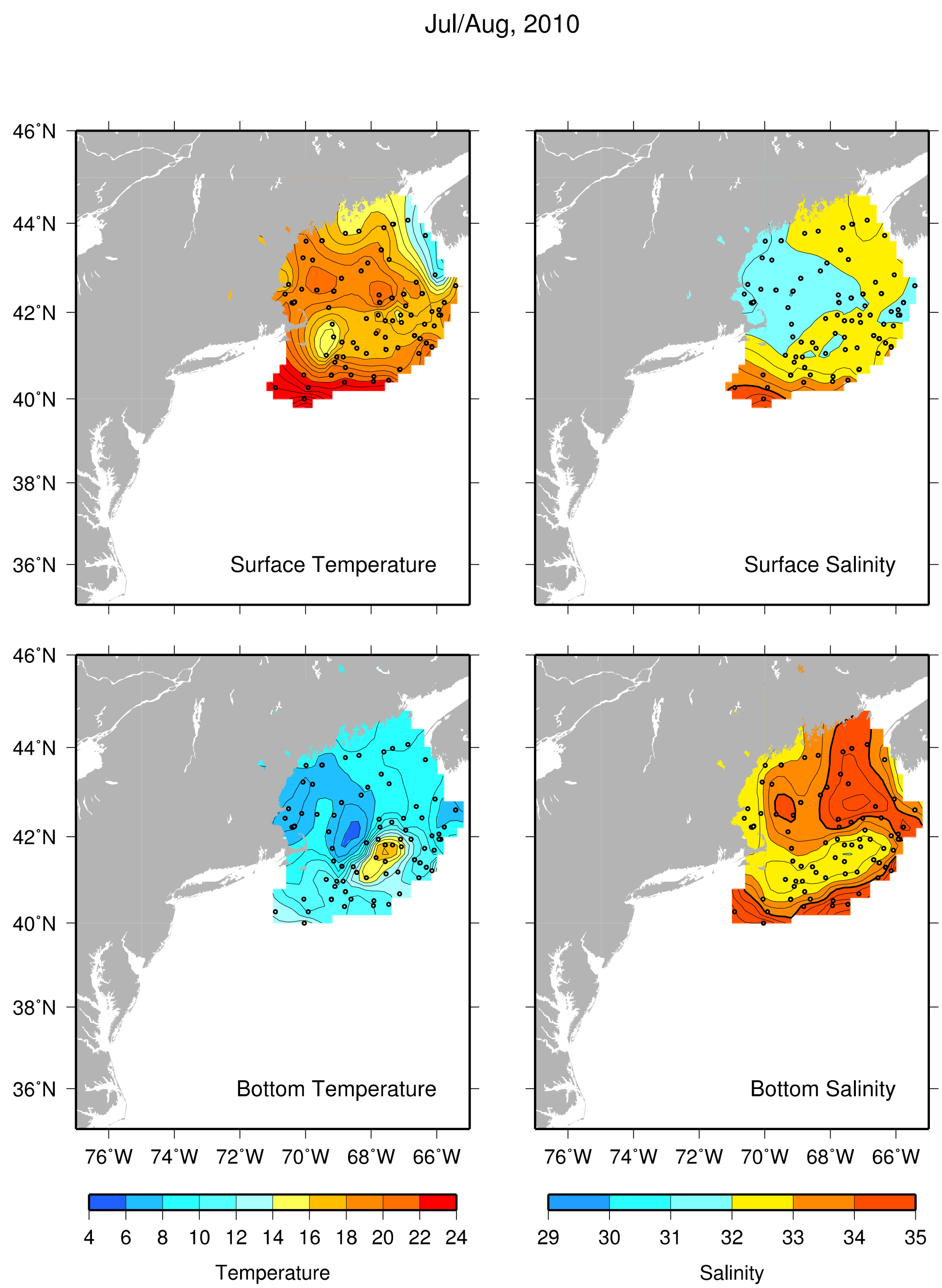

Figure 9a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during July-August 2010.Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

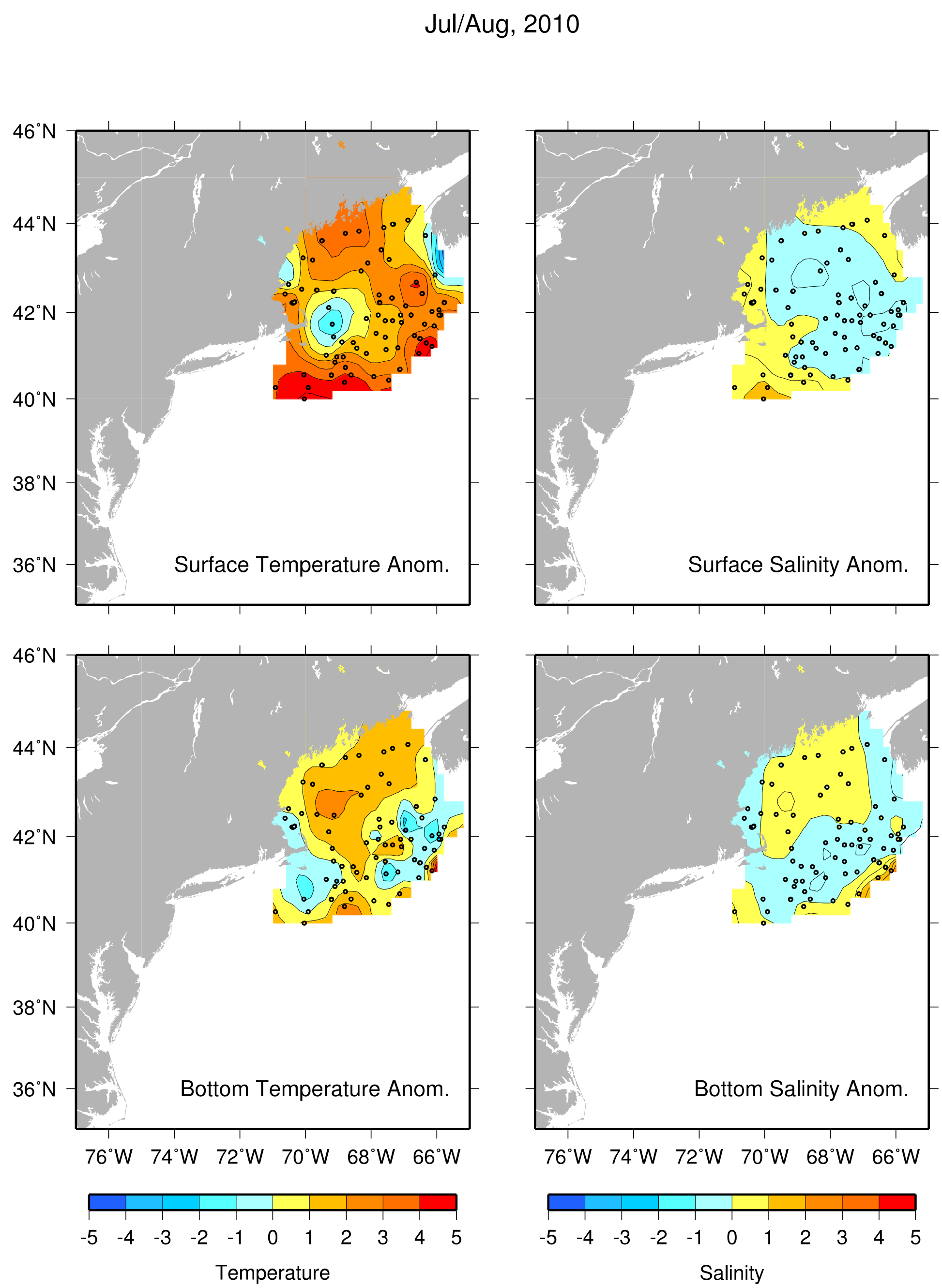

Figure 9b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during July-August 2010.Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

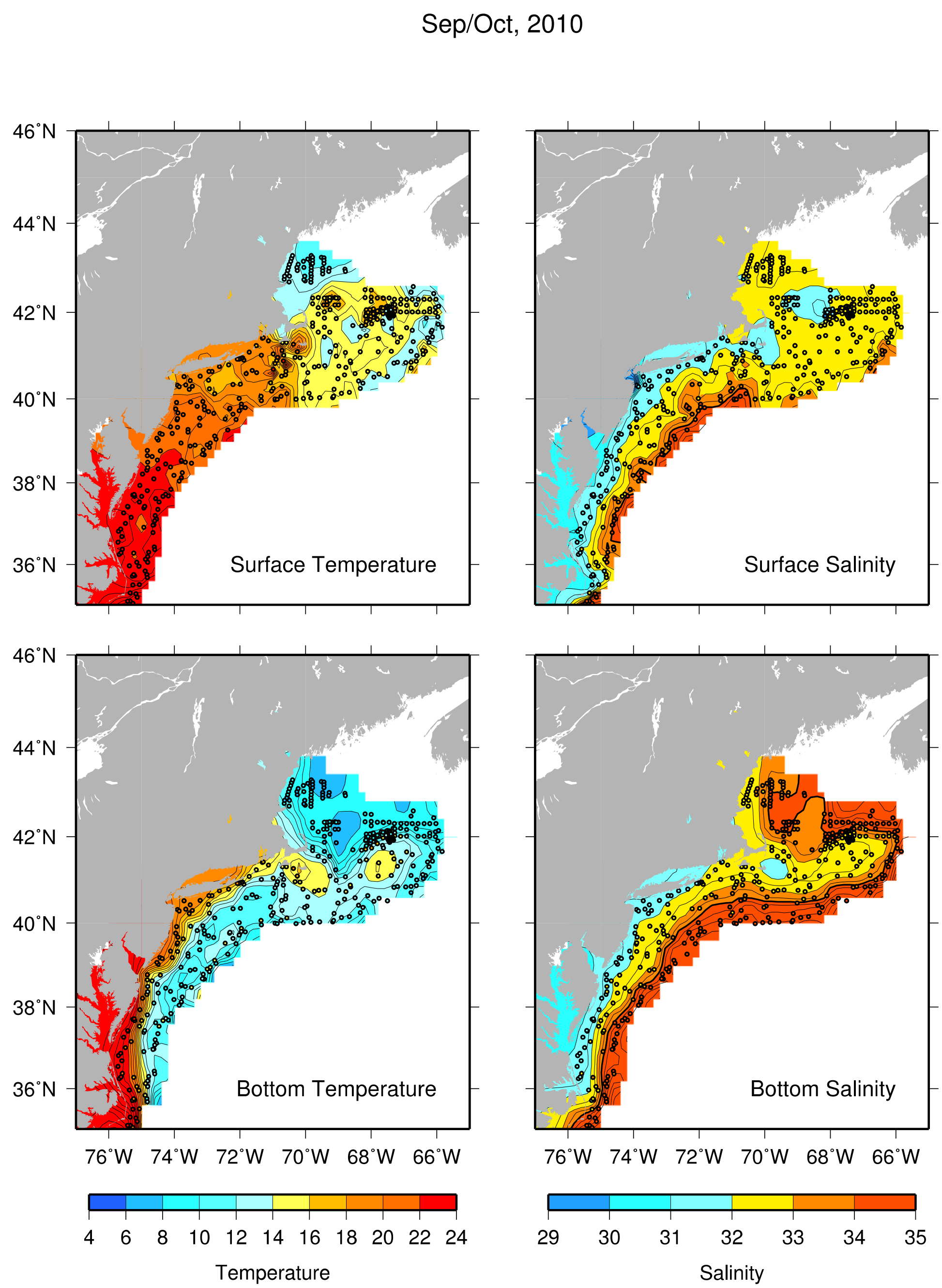

Figure 10a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during September-October 2010.Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

Sep/Oct, 2010

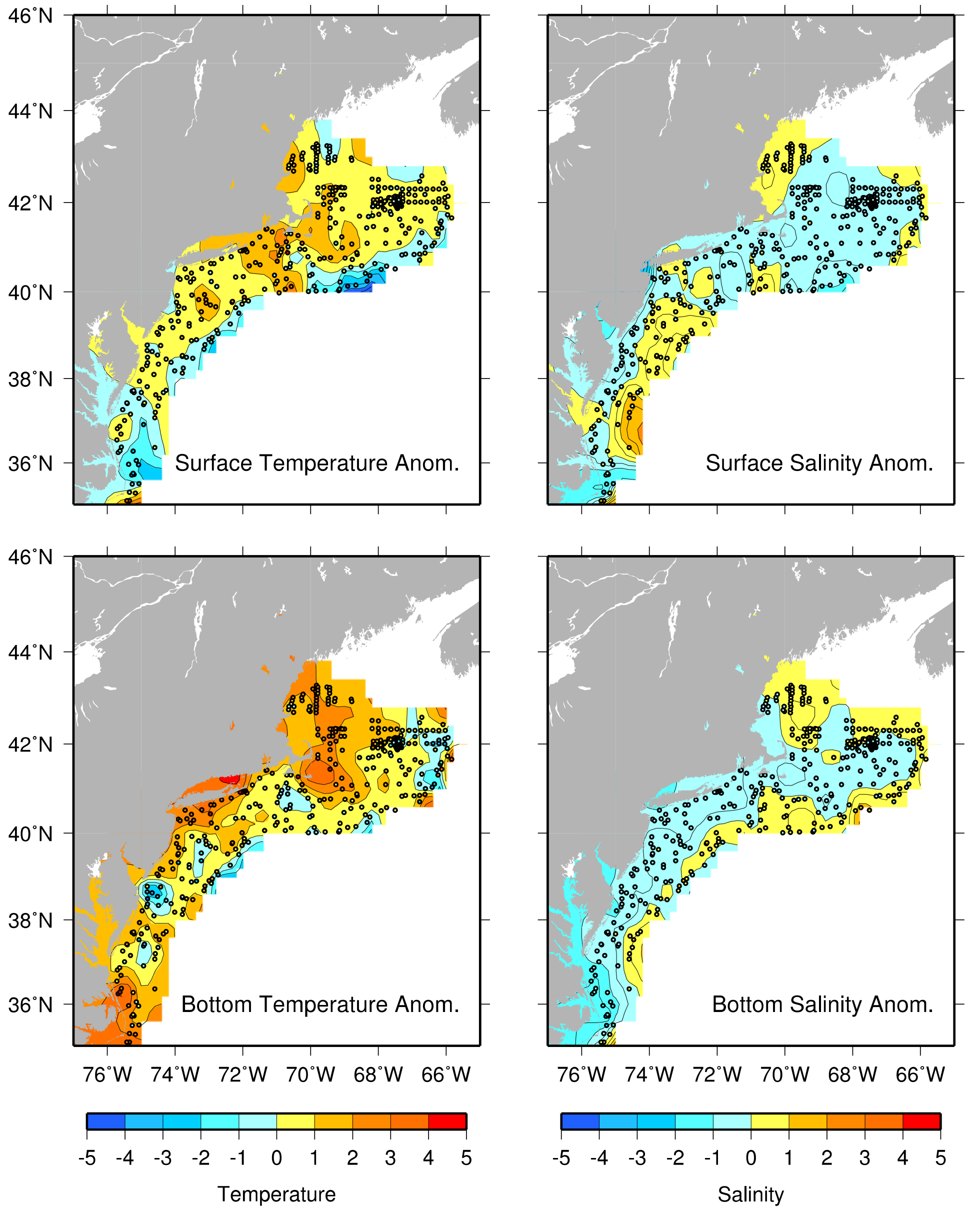

Figure 10b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during September-October 2010.Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

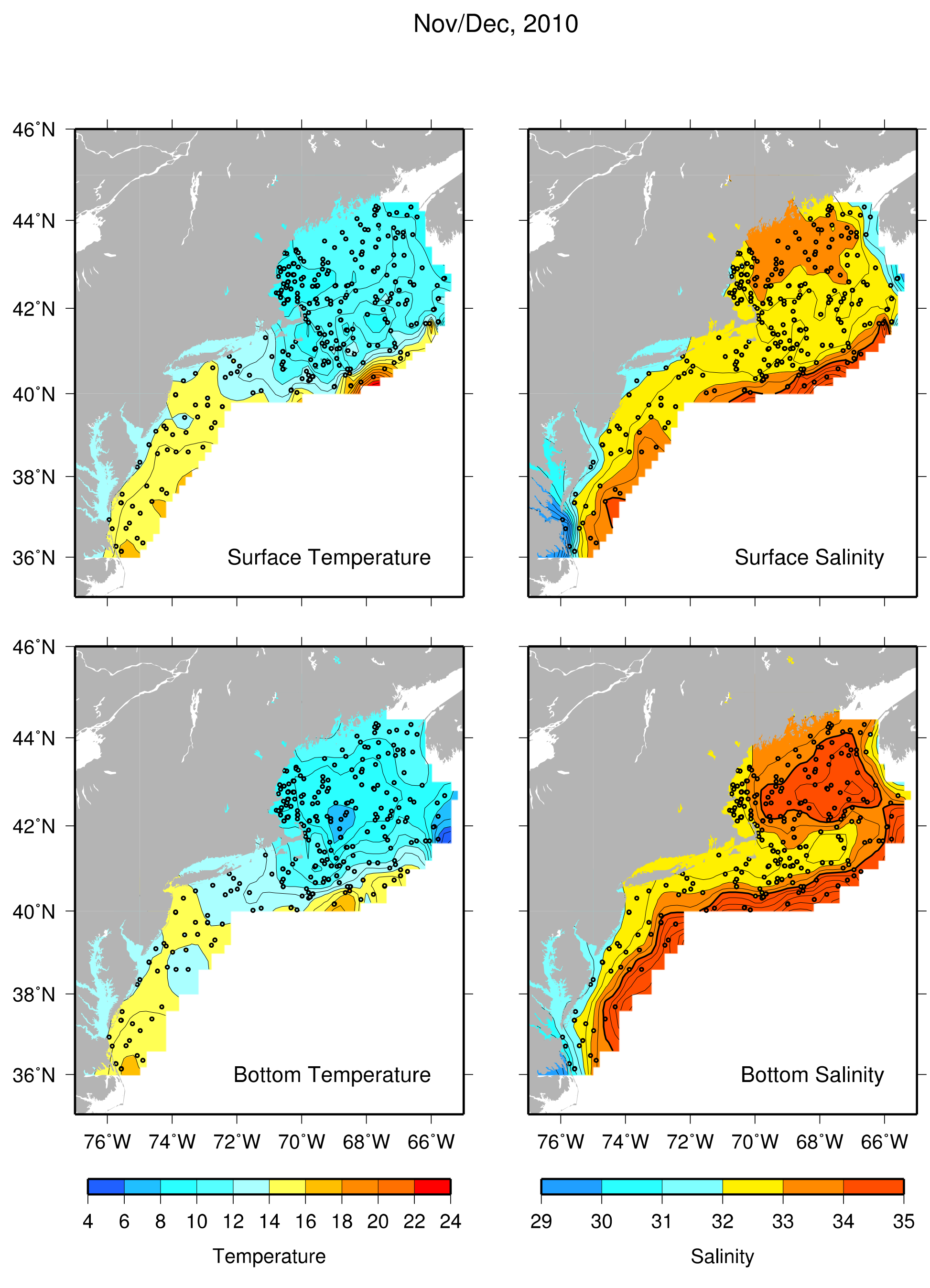

Figure 11a. Near-surface (top) and near-bottom (bottom) temperature (left) and salinity (right) distributions during November-December 2010.Temperature and salinity are contoured in increments of 1ºC and 0.5, respectively. The 34 isohaline is denoted by the heavier contour.

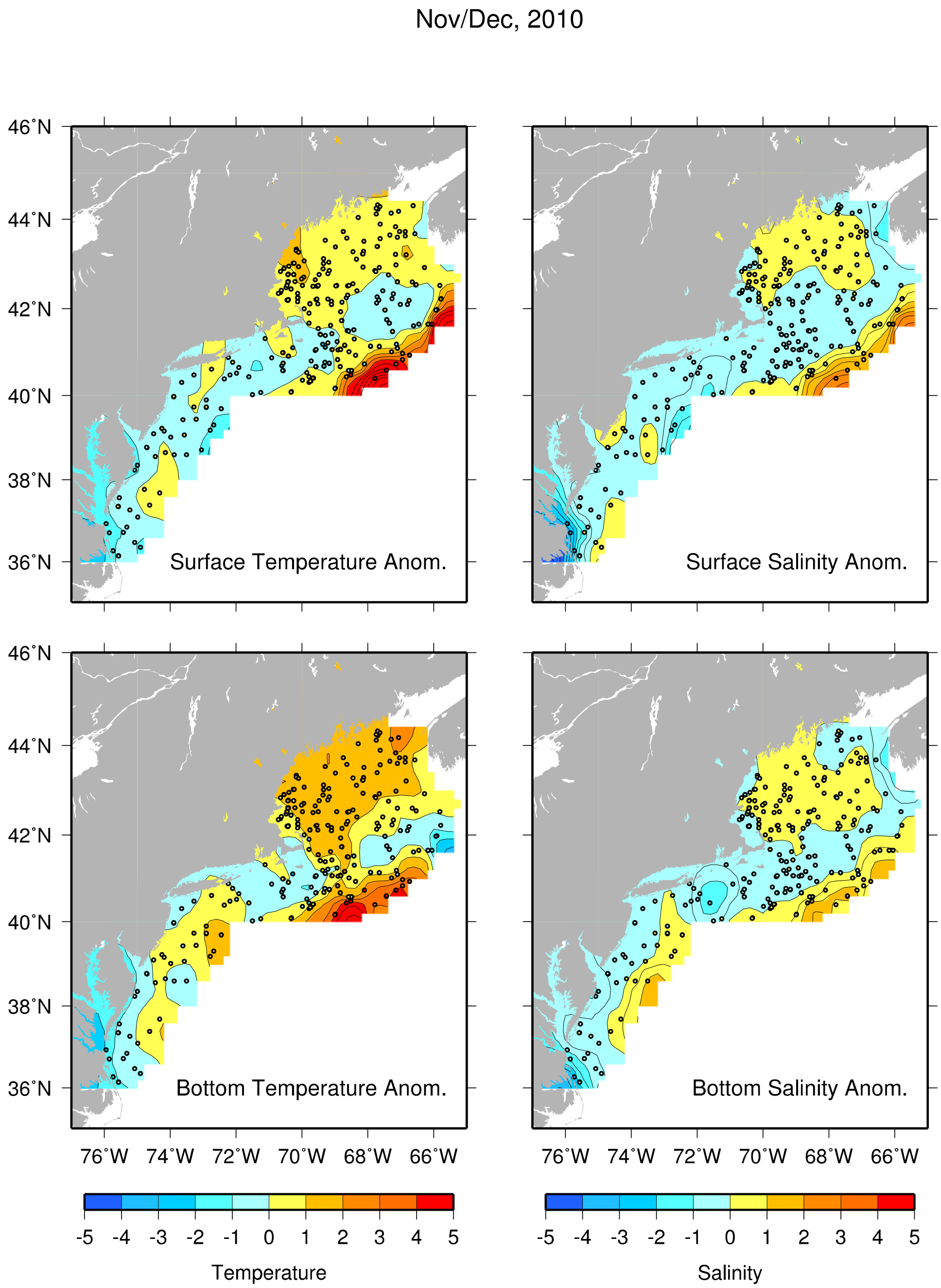

Figure 11b. Near-surface and near-bottom temperature anomaly (left) and salinity anomaly (right) distributions during November-December 2010.Temperature and salinity anomaly are contoured in increments of 1ºC and 0.5, respectively.

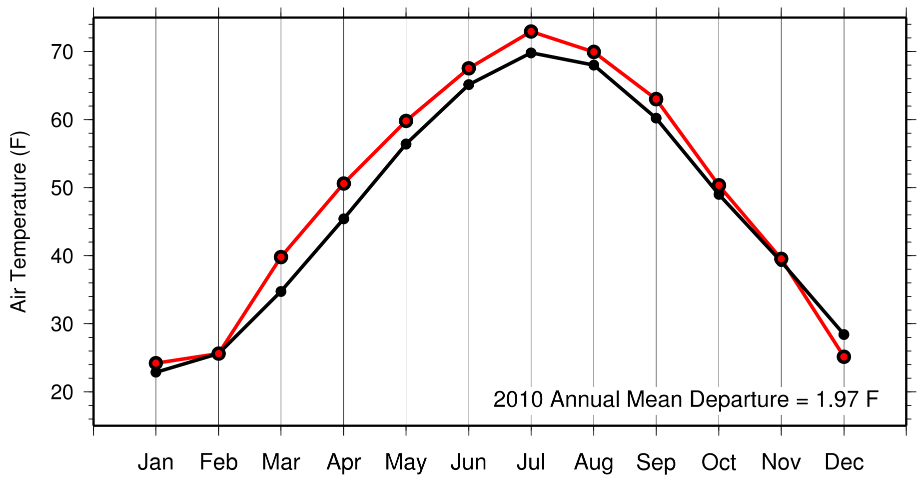

Figure 12. Monthly mean air temperature over the northeastern United States for the years 1971-2000 (black) and 2010 (red), plotted from climate summary data compiled by the Northeast Regional Climate Center (http://www.nrcc.cornell.edu). The northeast region encompasses coastal states from Maine to Maryland and inland states west to West Virginia.

APPENDIX

Table A1. 2010 regional average temperature and salinity values for individual cruises that sampled within the eastern Gulf of Maine (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Gulf of Maine East

			Surface					Bottom					
Cruise	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
DEL1001	46	2	4.59	-0.45	0.69	5.75	1	2	6.48	0.10	0.64	7.05	1
HB1002	105	31	5.25	0.44	0.17	0.92	0	28	7.77	1.14	0.19	0.79	0
DEL1004	158	22	10.93	1.44	0.21	1.67	1	16	8.55	1.28	0.24	2.19	1
S11001	172	9	13.37	3.29	0.31	6.92	1	9	8.55	-1.90	0.30	7.32	1
DEL1009	234	19	16.74	1.74	0.25	1.40	0	14	9.05	0.71	0.27	1.86	0
DEL1010	263	35	16.18	0.57	0.17	1.24	1	35	8.81	0.96	0.16	2.24	1
DEL1011	301	26	12.82	-0.47	0.18	0.53	1	26	11.55	-1.39	0.18	1.85	1
HB1005	313	26	11.23	0.25	0.19	0.60	0	26	9.59	1.14	0.20	1.12	0
DEL1012	323	16	10.65	0.67	0.23	0.61	0	11	9.54	1.12	0.27	1.37	0

			Surface					Bottom					
Cruise	CD	#obs	Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Salinity	Anomaly	SDV1	SDV2	Flag
DEL1001	46	2	32.55	-0.57	0.43	2.63	1	2	33.48	-0.20	0.41	3.01	1
HB1002	105	31	31.83	-0.69	0.12	0.42	0	28	33.99	0.00	0.10	0.45	0
DEL1004	158	22	32.00	-0.44	0.14	0.68	1	16	33.82	0.08	0.14	1.01	1
S11001	172	9	31.99	-0.79	0.18	1.30	1	9	32.46	-0.35	0.18	1.37	1
DEL1009	234	19	32.22	-0.15	0.19	0.34	0	14	34.23	-0.02	0.15	0.37	0
DEL1010	263	35	32.12	-0.24	0.11	0.79	1	35	34.50	0.16	0.10	0.79	1
DEL1011	301	26	32.22	-0.38	0.11	0.12	1	26	32.43	-0.20	0.11	0.21	1
HB1005	313	26	32.79	0.04	0.13	0.38	0	26	34.48	0.06	0.10	0.33	0
DEL1012	323	16	32.74	0.09	0.16	0.26	0	11	34.12	0.00	0.15	0.36	0

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A2. 2010 regional average temperature and salinity values for individual cruises that sampled within the western Gulf of Maine (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Gulf of Maine West

Cruise	CD	#obs	Surface Temp	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Temp	Anomaly	SDV1	SDV2	Flag
DEL1001	47	37	4.74	0.07	0.19	0.99	1	31	5.49	0.83	0.18	1.33	1
HB1002	113	56	7.04	1.56	0.15	0.93	0	55	6.11	1.01	0.13	0.69	0
DEL1004	158	27	13.36	2.49	0.19	0.90	0	48	6.93	1.10	0.19	1.67	1
S11001	178	13	16.06	3.06	0.31	4.63	1	13	6.96	0.70	0.28	4.86	1
DEL1009	234	23	18.40	1.60	0.22	1.53	0	21	7.59	1.22	0.19	1.20	0
DEL1010	280	82	14.33	0.53	0.12	0.69	1	79	8.09	1.84	0.10	1.32	1
HB1005	318	44	10.74	0.54	0.16	0.71	0	43	8.93	1.42	0.14	0.94	0
DEL1012	329	54	9.66	0.59	0.15	2.23	1	47	8.88	1.43	0.15	2.22	1

Cruise	CD	#obs	Surface Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Salinity	Anomaly	SDV1	SDV2	Flag
DEL1001	47	37	32.57	-0.28	0.13	0.45	1	31	32.89	-0.30	0.11	0.56	1
HB1002	113	56	31.60	-0.87	0.10	0.41	0	55	33.04	-0.30	0.07	0.41	0
DEL1004	158	27	31.41	-0.64	0.12	0.40	0	48	33.27	-0.11	0.11	0.75	1
S11001	178	13	31.61	-0.42	0.18	0.87	1	13	32.38	-0.43	0.16	0.92	1
DEL1009	234	23	31.81	-0.17	0.14	0.34	0	21	33.42	0.09	0.12	0.37	0
DEL1010	280	80	32.21	-0.12	0.08	0.52	1	79	33.87	0.25	0.06	0.48	1
HB1005	318	44	32.81	0.05	0.11	0.32	0	43	33.74	0.14	0.08	0.29	0
DEL1012	329	54	32.76	0.00	0.10	0.88	1	47	33.45	0.12	0.08	0.79	1

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A3. 2010 regional average temperature and salinity values for individual cruises that sampled within the Georges Bank area (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Georges Bank

			Surface						Bottom				
Cruise	CD	#obs	Temp	Anomaly	SDV1	SDV2	Flag	#obs	Temp	Anomaly	SDV1	SDV2	Flag
DEL1001	45	30	5.40	-0.16	0.21	0.60	0	27	5.82	-0.07	0.25	1.11	0
HB1002	98	58	6.81	1.67	0.14	1.42	0	46	6.60	1.43	0.16	0.93	0
DEL1004	154	42	10.96	1.27	0.16	0.90	0	28	8.65	0.71	0.22	1.10	0
S11001	167	49	12.13	1.51	0.17	1.72	0	46	9.15	0.87	0.18	1.94	0
DEL1009	241	41	18.73	2.54	0.18	1.48	0	36	12.53	0.24	0.17	1.88	1
DEL1010	269	19	15.67	0.63	0.21	0.69	1	18	12.05	-0.84	0.22	2.34	1
HB1005	298	56	13.97	-0.08	0.14	1.27	0	38	12.67	0.46	0.19	1.08	0
DEL1011	302	71	12.79	-0.43	0.11	0.27	1	71	12.20	-0.66	0.11	0.95	1
DEL1012	326	56	12.32	0.80	0.14	1.73	0	49	11.94	0.98	0.16	1.63	0

			Surface						Bottom				
Cruise	CD	#obs	Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Salinity	Anomaly	SDV1	SDV2	Flag
DEL1001	45	30	32.94	-0.13	0.12	0.29	0	27	33.09	-0.13	0.15	0.43	0
HB1002	98	58	32.83	-0.17	0.08	0.75	0	46	32.91	-0.24	0.10	0.47	0
DEL1004	154	42	32.30	-0.55	0.10	0.27	0	28	32.52	-0.57	0.13	0.47	0
S11001	167	49	32.16	-0.58	0.10	0.33	0	46	32.64	-0.39	0.11	0.38	0
DEL1009	241	41	32.32	-0.32	0.11	0.43	0	36	32.51	-0.30	0.10	0.71	1
DEL1010	269	19	32.19	-0.35	0.13	0.12	1	18	32.61	-0.12	0.13	0.35	1
HB1005	298	56	32.41	-0.36	0.09	0.37	0	38	32.90	-0.21	0.11	0.42	0
DEL1011	302	71	32.25	-0.36	0.06	0.06	1	71	32.36	-0.27	0.06	0.11	1
DEL1012	326	56	33.04	0.20	0.09	0.68	0	49	33.24	0.23	0.09	0.60	0

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A4. 2010 regional average temperature and salinity values for individual cruises that sampled within the northern Middle Atlantic Bight (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Northern Mid Atlantic Bight

Cruise	CD	#obs	Surface Temp	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Temp	Anomaly	SDV1	SDV2	Flag
DEL1001	38	15	5.70	-0.39	0.32	1.52	1	13	6.52	0.19	0.34	1.89	1
HB1002	84	56	6.16	1.60	0.17	1.45	0	48	6.01	0.88	0.22	1.44	0
DEL1004	150	34	13.83	1.92	0.23	1.11	0	28	7.90	0.76	0.25	1.59	0
S11001	156	14	14.59	1.48	0.34	1.92	1	14	7.15	0.30	0.33	2.26	1
DEL1009	244	7	22.62	3.80	0.46	0.63	1	6	10.41	-0.94	0.50	1.08	1
HB1005	282	61	17.60	0.62	0.17	1.31	0	46	13.81	1.26	0.22	1.73	0
DEL1012	320	41	12.87	-0.20	0.23	0.84	0	36	12.64	-0.02	0.25	1.00	0

Cruise	CD	#obs	Surface Salinity	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Salinity	Anomaly	SDV1	SDV2	Flag
DEL1001	38	15	33.02	-0.14	0.23	0.83	1	13	33.37	-0.11	0.20	0.77	1
HB1002	84	56	32.34	-0.54	0.11	2.44	0	48	32.85	-0.50	0.13	0.47	0
DEL1004	150	34	31.95	-0.49	0.15	0.29	0	28	32.65	-0.49	0.16	0.56	0
S11001	156	14	31.67	-0.46	0.22	0.83	1	14	32.72	-0.28	0.20	0.55	1
DEL1009	244	7	33.03	0.44	0.28	0.53	1	6	32.73	-0.37	0.31	0.41	1
HB1005	282	61	32.58	-0.17	0.11	0.65	0	46	33.00	-0.34	0.14	0.54	0
DEL1012	320	41	32.57	-0.39	0.15	0.36	0	36	32.94	-0.46	0.15	0.47	0

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A5. 2010 regional average temperature and salinity values for individual cruises that sampled within the southern Middle Atlantic Bight (boundaries defined in Figure 1.) Average values incorporating less than 10 observations are shown in gray.

Southern Mid Atlantic Bight

Cruise	CD	#obs	Surface Temp	Anomaly	SDV1	SDV2	Flag	#obs	Bottom Temp	Anomaly	SDV1	SDV2	Flag
DEL1001	37	33	6.35	0.36	0.23	0.85	1	30	6.31	0.85	0.24	0.83	1
DEL1002	60	9	7.69	-0.07	0.42	0.87	1	2	5.69	-0.21	0.94	2.51	1
HB1002	68	96	5.59	-0.07	0.13	1.44	0	82	5.32	-0.33	0.16	1.32	0
S11001	136	52	12.66	0.16	0.18	0.75	1	51	6.99	-0.86	0.20	1.13	1
DEL1004	149	65	16.02	0.42	0.19	1.18	1	35	9.48	-0.45	0.23	1.65	1
HB1005	260	94	21.84	-0.04	0.13	1.11	0	80	14.78	0.62	0.16	1.95	0
DEL1012	312	43	14.89	-0.34	0.21	0.65	0	38	14.45	-0.03	0.22	0.93	1
Cruise	**CD**	**#obs**	**Surface Salinity**	**Anomaly**	**SDV1**	**SDV2**	**Flag**	**#obs**	**Bottom Salinity**	**Anomaly**	**SDV1**	**SDV2**	**Flag**
DEL1001	37	32	33.37	0.17	0.18	0.53	1	29	33.51	0.32	0.15	0.44	1
DEL1002	60	9	34.13	0.00	0.29	0.34	1	2	33.98	0.49	0.58	1.49	1
HB1002	68	96	32.81	-0.32	0.10	2.19	0	82	33.16	-0.30	0.10	0.53	0
S11001	136	51	31.63	-1.03	0.13	0.41	1	51	33.16	-0.46	0.12	0.25	1
DEL1004	149	65	31.46	-0.68	0.15	0.46	1	35	32.18	-0.87	0.14	0.36	1
HB1005	260	94	32.42	0.14	0.10	0.79	0	80	32.80	-0.46	0.10	0.71	0
DEL1012	312	43	32.51	-0.32	0.16	0.92	0	38	32.81	-0.25	0.14	0.57	1

"Cruise", the code name for a cruise:
CD, the calendar mid-date of all the stations within a region for that cruise:
"#obs", the number of observations included in each average:
"Temp", the areal average temperature: "Salt", the areal average salinity:
Anomaly, the areal average temperature or salinity anomaly:
"SDV1",the standard deviation associated with the average temperature or salinity anomaly:
"SDV2", the standard deviation of the individual anomalies from which the average anomaly was derived:
Flag, a value of "1" indicates that a true areal average could not be calculated due to poor station coverage.
The areal averages listed were derived from a simple average of the observations within the region.

Table A6. 2010 temperature, salinity, and volume of the shelf water (SHW) in the Middle-Atlantic Bight North (MABN) and South (MABS) during 2010. The shelf water is defined as water within the upper 100 meters having salinity less than 34.

CD	Temp	Temp. Anomaly	Salt	Salt Anomaly	SHW Temp	SHW T. Anom	SHW Salt	SHW S. Anom	SHW Volume	SHW Vol. Anomaly
					MABN					
84	6.55	0.99	33.04	-0.30	5.78	1.29	32.72	-0.32	2107.10	29.67
150	9.55	0.09	32.62	-0.60	9.39	0.60	32.47	-0.38	2390.77	470.85
158	9.39	-0.61	32.37	-0.85	9.39	0.02	32.37	-0.46	2332.11	409.47
283	15.60	0.61	33.48	-0.18	15.39	0.85	32.65	-0.28	1660.85	192.26
323	12.76	-0.90	32.89	-0.84	12.51	-0.49	32.67	-0.38	2190.17	820.51
					MABS					
37	7.93	-0.87	33.95	-0.22	5.37	-0.22	33.24	-0.02	1201.07	30.12
69	6.87	-1.06	33.64	-0.35	5.50	0.37	33.13	-0.25	2221.52	909.73
136	8.73	-1.31	32.66	-0.77	8.71	-0.80	32.62	-0.23	3793.67	1858.63
150	11.27	0.29	32.55	-0.79	10.98	0.43	32.17	-0.52	2565.02	500.58
260	16.68	0.25	33.43	-0.07	16.87	0.61	32.53	-0.39	2205.91	71.69
312	14.94	0.24	33.37	-0.57	14.79	-0.16	32.79	-0.26	2099.04	461.76

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